



U.S. DEPARTMENT OF  
**ENERGY**

Legacy  
Management

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# Performance of an In Situ Hydroxyapatite Permeable Reactive Barrier at the Old Rifle Uranium Processing Mill Site

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## 2.1 Groundwater Compliance Challenges

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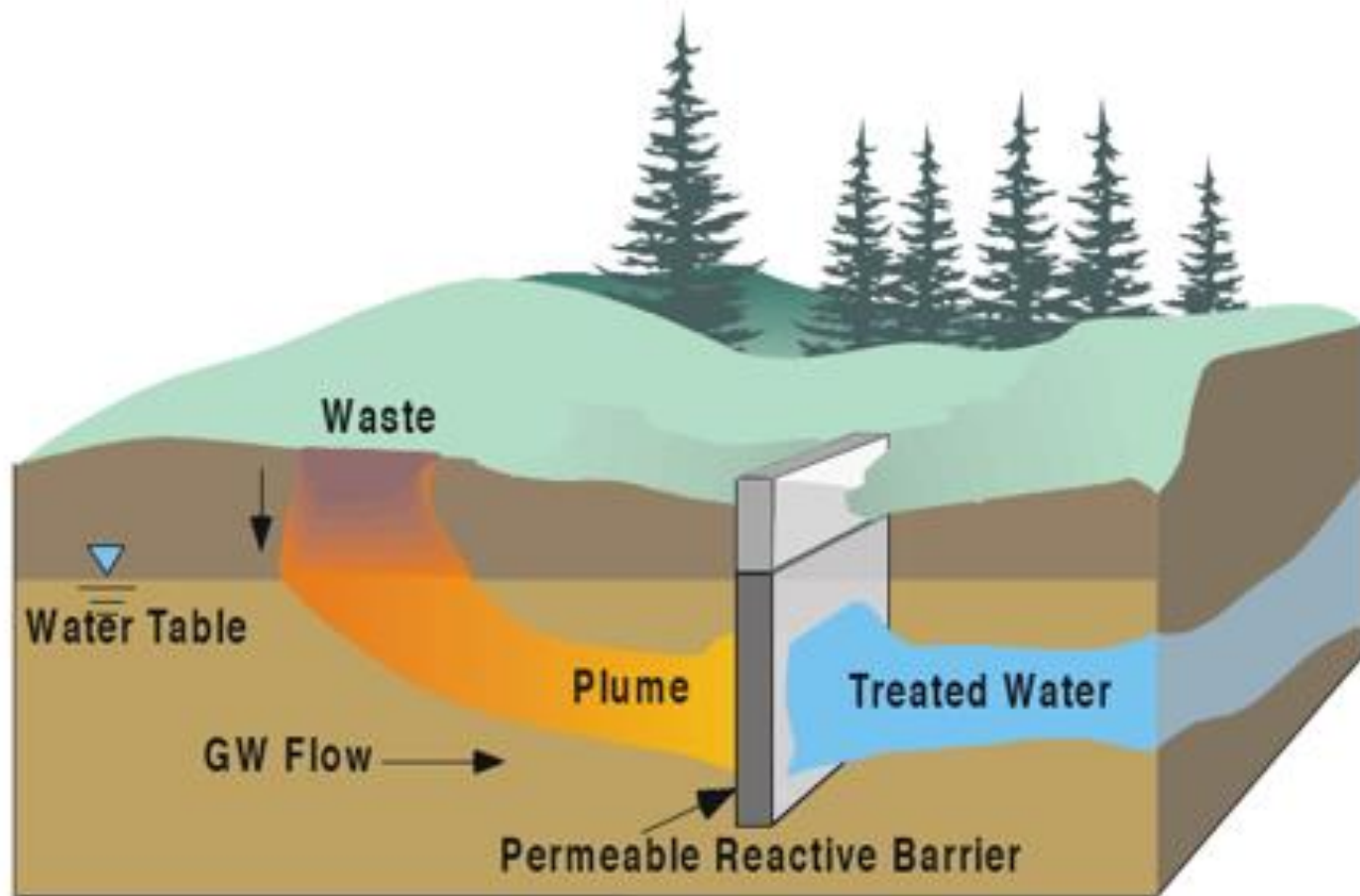
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# Presentation Outline

- Overview of Apatite Permeable Reactive Barriers (PRBs)
- The Old Rifle Site
- Deployment of the Apatite PRB at the Old Rifle Uranium Mill Site
- Performance of the Apatite PRB for Uranium Remediation
- Summary

# Permeable Reactive Barrier (PRB) Technology



# Conventional PRB Construction



**Trenching Followed by  
Backfilling with a Reactive Media**

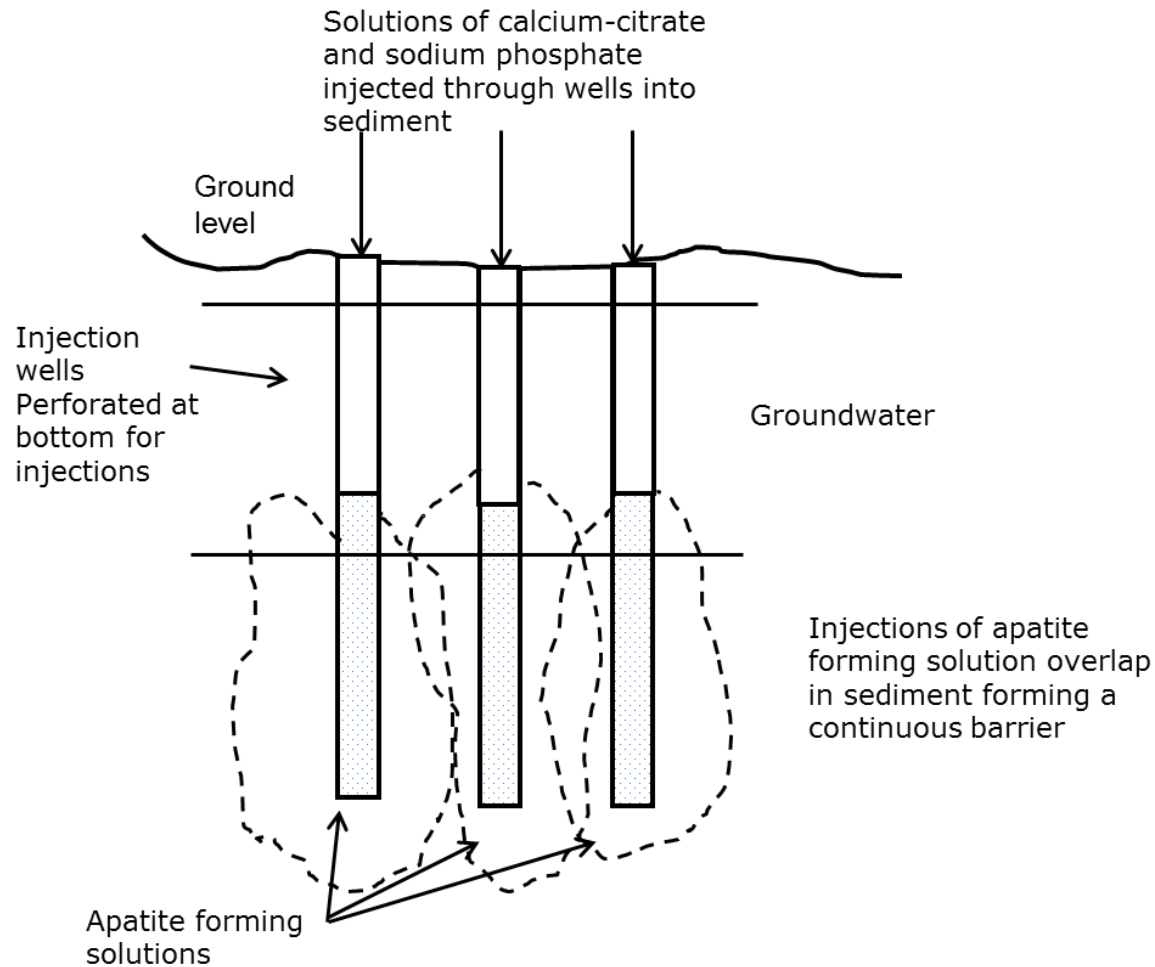


**Jet or Grout Injection of  
A Reactive Media**

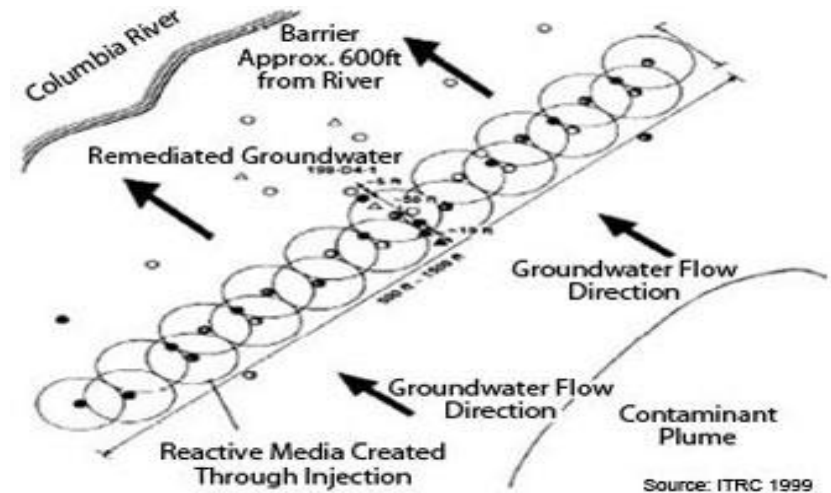
# Apatite as a PRB Material

- Composed of calcium phosphate,  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$
- Common mineral in the environment and as a main component of bone and teeth.
- Very stable in the environment, extremely low solubility.
- Can be used to sequester a wide variety of radionuclides, heavy metals and other contaminants through substitution into the structure or sorption onto the surface as metal phosphate compounds.
- The high affinity for these contaminants, stability and very low solubility make apatite an ideal sorbent for immobilization of many contaminants.
- Can be formed in situ by solution injection in the subsurface...

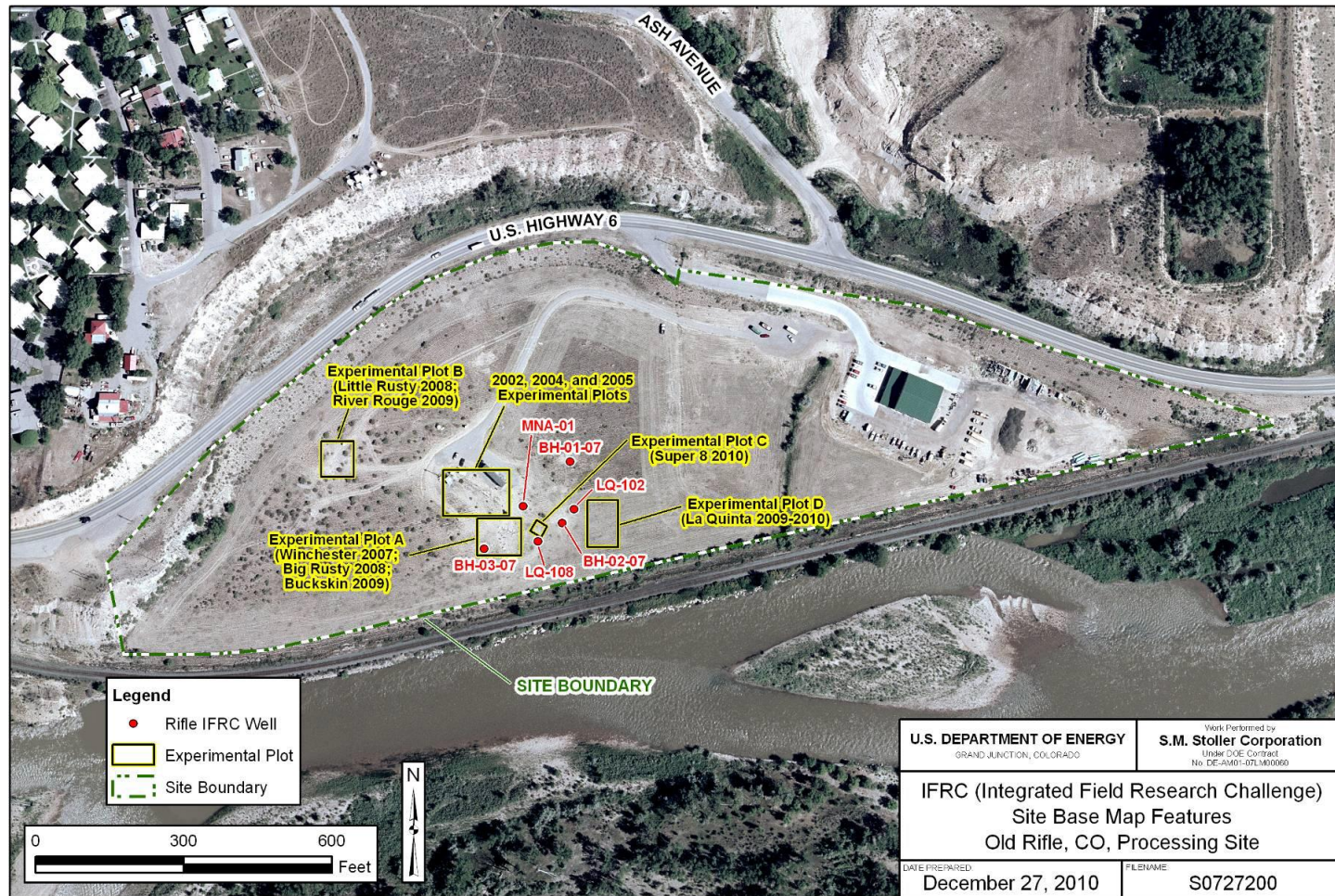
# Forming an Apatite PRB



# Successfully Deployed at the Hanford Site

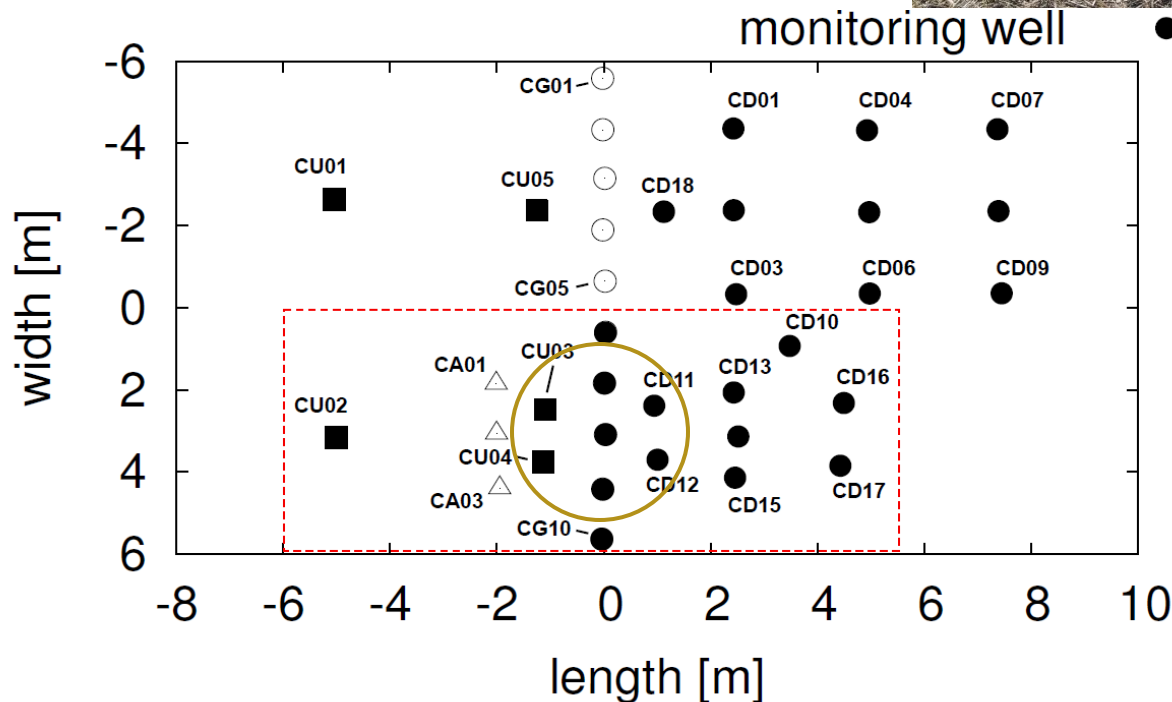
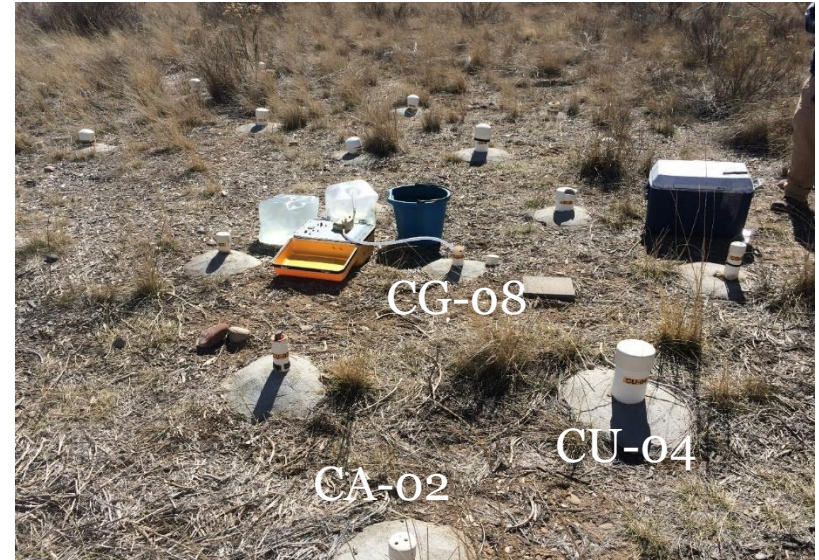


# Old Rifle Site IFRC Experimental Plots



# Plot C Wells - Apatite Injection Experiment

flow direction  
→



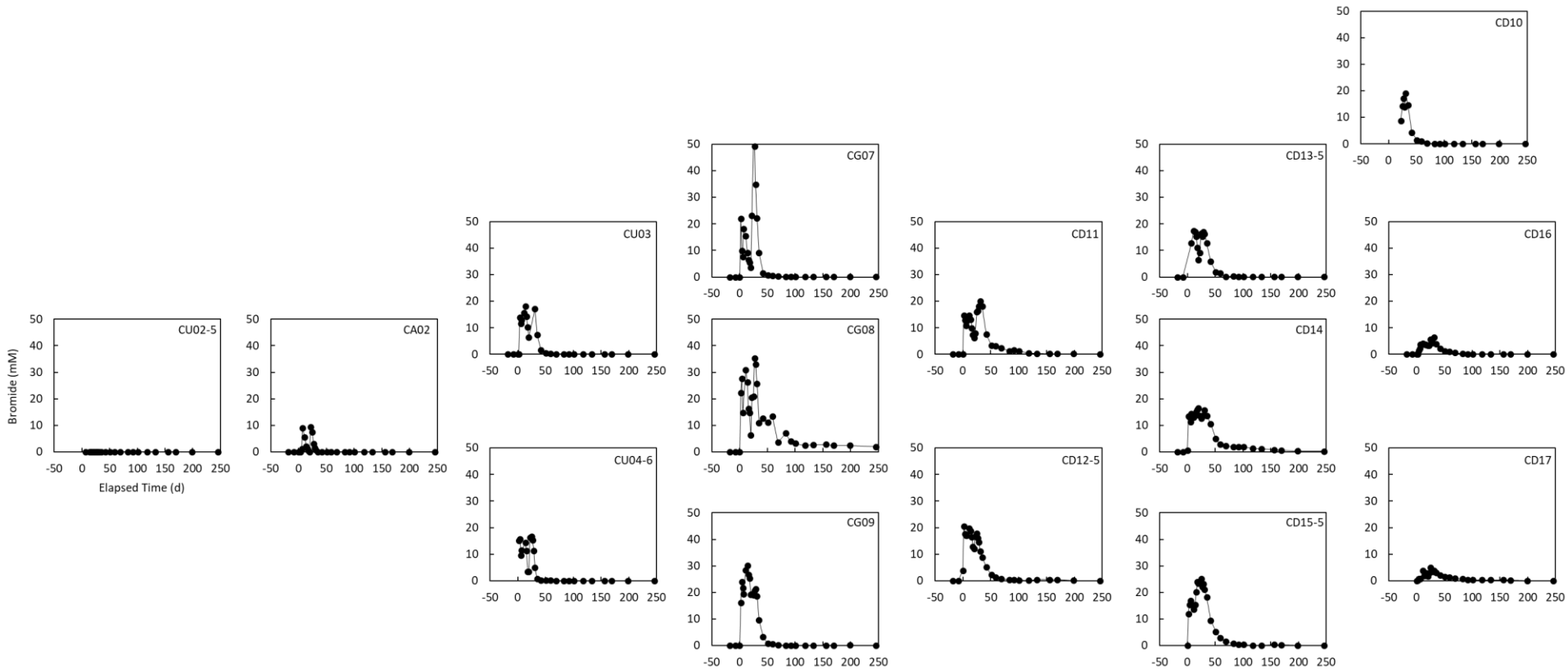
# Field Deployment of Apatite Forming Solutions

- Injection Formulation:
  - Tank A: Solution containing 40mM of  $\text{Ca}^{2+}$ , 100mM citrate and 40mM Bromide
  - Tank B: solution containing 40mM phosphate
- Injection of 4,800 gallons of solution total (~ 5 pore volumes)
- Three injections total. (Nov. 14<sup>th</sup>, 21<sup>st</sup>, and Dec. 5<sup>th</sup>, 2017).
- Injection Rate Varied: ~4 to 16 liters per minute.
- Injections completed within 24 to 56 hours.
- Maintained tank temperature at 20-25 C.
- Primary injection well is CG-08.

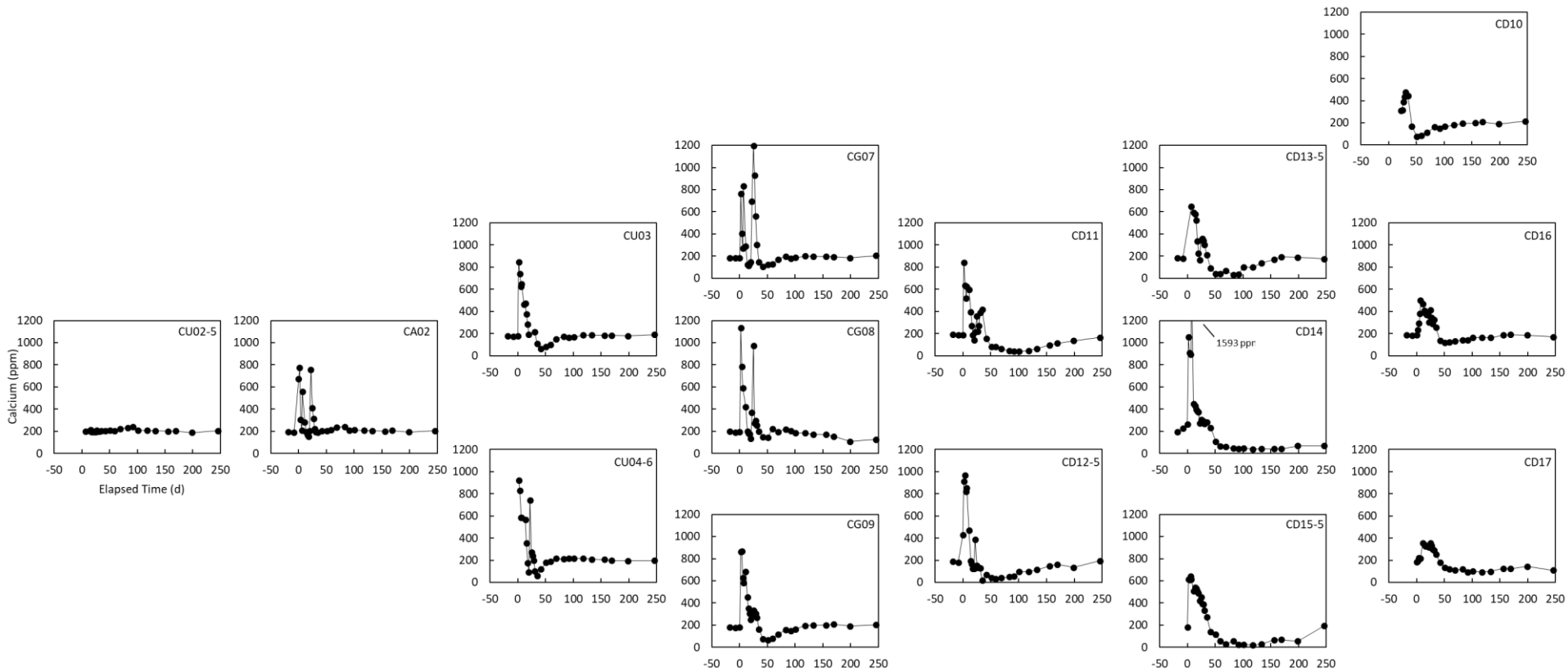
# Field Deployment of Apatite Forming Solutions



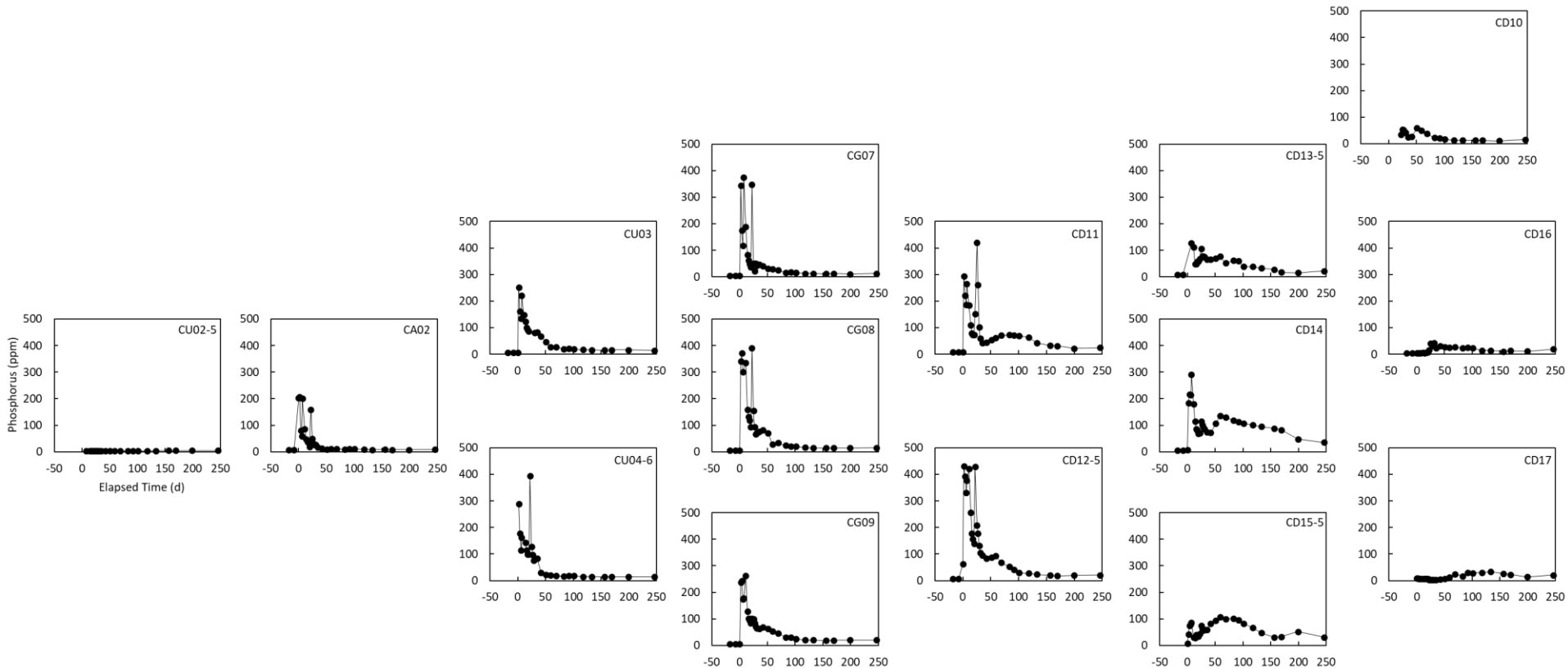
# Bromide Concentrations (ppm)



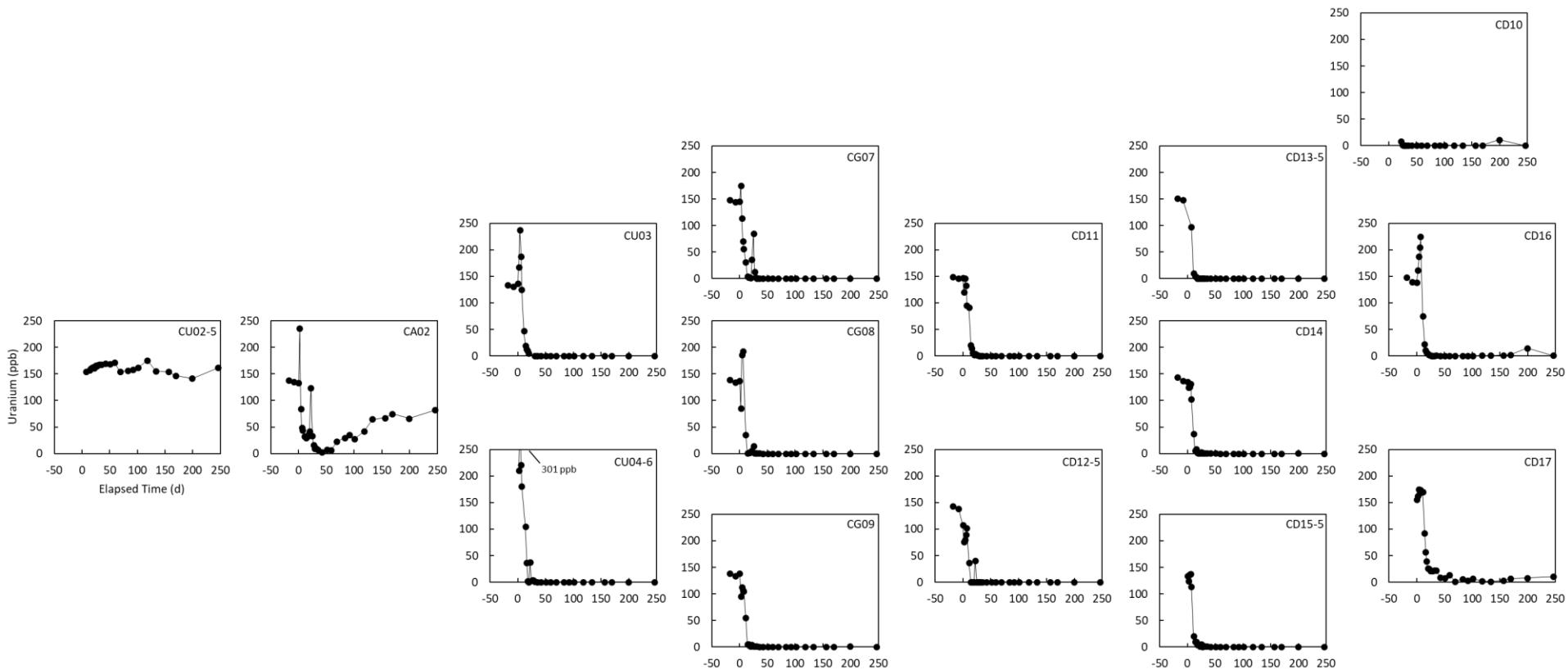
# Calcium Concentrations (ppm)



# Phosphorous Concentrations (ppm)



# Uranium Concentrations (ppb)



# Summary

- Apatite is an effective sorbent for a variety of radionuclides and heavy metals.
- It can be deployed as a Permeable Reactive Barrier (PRB) by injecting simple aqueous-based solutions directly into the subsurface.
- The apatite PRB field experiment indicates very effective uptake of uranium after more than 200 days of monitoring.
- Low cost deployment as compared to traditional PRB deployments that is also minimally invasive to the site.